INERTIAL CONFINEMENT FUSION
Lawrence Livermore National Laboratory
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Bimonthly Update

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Multi-Lab Hydrodynamic Jet Experimental Campaign

The formation of a jet of material from the interaction of a shock wave with a density perturbation is a problem of basic scientific interest with specific application to astrophysics and inertial confinement fusion (ICF). During a three-week campaign on the National Ignition Facility (NIF), a multi-lab collaboration between LLNL and LANL performed a series of experiments to gain a detailed scientific understanding of the physics of hydrodynamic jets. This work was done in collaboratin with the Defense and Nuclear Technolgoies Directorate at LLNL. The results of these experiments validated NIF as a platform for hydrodynamics experiments by providing high-quality data to compare with three-dimensional (3D) codes. These experiments also satisfied a National Nuclear Security Administration (NNSA) Level 1 milestone to provide stockpile stewardship data on NIF. Results have been documented in several publications including *Physical Review Letters*,[1] *Physics of Plasmas*,[2] and *Review of Scientific Instruments*.[3]

The experiments were conducted using the first quad (4 beams) of NIF. A 1.5-ns, 6-kJ (2 x 3 kJ beams), 3ω (351- nm wavelength), 1000-μm-diameter laser pulse was used to drive a 40-Mbar shock wave into aluminum targets backed by 100-mg/cc carbon aerogel foam (see Figure 1). As the high-pressure shock propagated into the target, the aluminum was heated to a temperature of approximately 20 eV, at which point it was in the plasma state. When the shock hit the perturbation, plasma was ejected into the void. This aluminum plasma then expanded into the foam in the form of a supersonic jet. A third laser beam, delayed in time by either 16 or 22 ns, created a point source of x-rays. These x-rays were used to capture a snapshot of the jet's hydrodynamic evolution via transmission radiography (see Jan.-Feb. 2004 *ICF Bimonthly Update*).

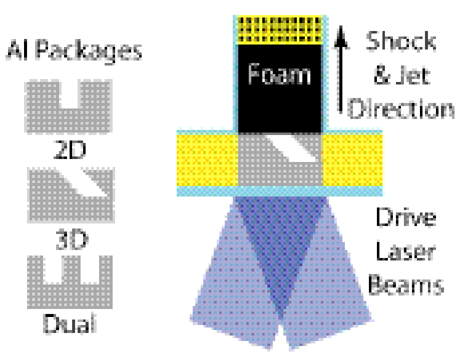

Figure 1. Schematic of target. The aluminum disk in the package had one of three different perturbations to generate a 2D, 3D, or dual jet.

X-ray radiographs of 2D, 3D, and dual jets are shown in Figure 2. Several key features of the jets observed in these experiments include: a pedestal of Al flowing down the shock tube behind the shock front, a compressed region of foam preceding the Al pedestal due to shock propagation in the foam itself, a jet of Al propagation ahead of the main shock into the uncompressed foam, and an associated bow shock. All jets consist of ~4 mg of aluminum traveling at ~30 km/sec, however, significant differences exist between the 2D and 3D jets. First, the 2D jet is aligned along the axis of the hole in the Al disk while, counterintuitively, the mass of the 3D jet is not ejected along the axis of the hole. In the regime of strong shocks, the mass flow is controlled by the shock trajectory, and thus, the mass is ejected approximately normal to the shock. A second difference is that the 3D jet has considerably more complicated structure and is more diffuse than the 2D jets, suggesting that the 3D structure is more unstable than the 2D.

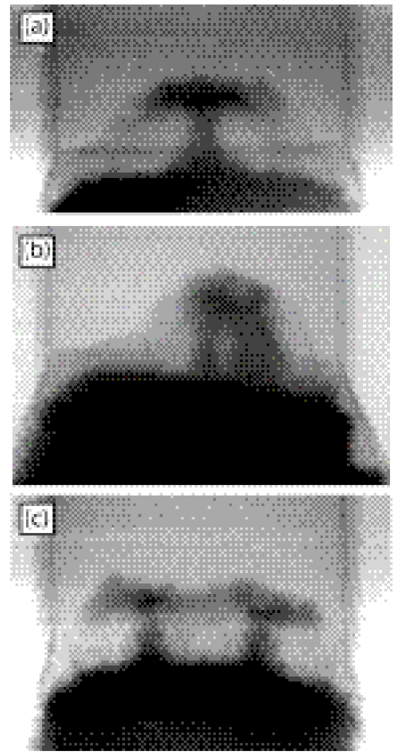

Figure 2. X-ray radiographs of 2D (a), 3D (b), and dual jets (c) at t = 22 ns.

Several codes were used to model the experiments. The codes were validated by comparing the spatial dimensions and the characteristic velocities of the jets. In addition, the high quality of the data permitted the total mass of jet material and its spatial mass distribution to be measured for the first time. Good agreement was found between the codes and the experiment.

These results demonstrate clear differences in jet shape and ejected mass as a function of perturbation geometry, consistent with modeling, and aid in our understanding of the complex hydrodynamics and physical processes in high-energy-density physics, including astrophysics and ICF.

[1] Phys Rev Lett, 94, 095005 (2005).
[2] Phys Plas 12, 056313 (2005).
[3] Rev Sci Instru 75, 3989 (2005) & 4775 (2005).

For comments about content of the ***Bimonthly Update***, contact Bruce A. Hammel (925) 422-3299.
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